TECHNICAL NOTES

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Pump Tests in New Mexico
USE OF MICROSOFT EXCEL SPREADSHEET

Purpose. This note is to provide background and basic instructions on how to use NMPumptests.xlsx, which is a Microsoft Office 10 Excel spreadsheet. To operate the spreadsheet the user will need to have a good understanding of Chapter 12 – Springs and Wells of the Engineering Field Handbook (Part 650 of the National Engineering Handbook). The spreadsheet must be downloaded from the New Mexico Share Point web site: https://ems-team.usda.gov/sites/NRCS_NewMexico/default.aspx, under the Engineering, Design Spreadsheet Library.

Pump tests are required by Conservation Practice Standard and Specification 642, Water Well. The spreadsheet provides information needed during the pump test and evaluates the data and information obtained by the pump test.

Background. In the past there was no provision to evaluate the aquifer transmissivity and storativity characteristics. These characteristics determine the aquifers ability to produce enough water to meet the resource need. Historically after well drilling was completed, the driller would develop the well by using repeated compressed air blasts to clean out the drilling mud contained in the casing. As the repeated compressed air blasts are done, less drilling mud and more water would be ejected from the casing. The driller would make an educated guess on what the well would produce based on the 'art' of interpreting the how many times air purging of the well would clean out the drilling mud and how much water would come up mixed with the mud. This technique of estimation varies between drillers and is not qualitative, much less quantitative in providing an accurate determination of what the aquifer will produce.

Then a pump would be arbitrarily selected based on the depth to water and the installer, producer and NRCS representative would hope the aquifer could match the pump performance curves without over pumping the well, where water surface reaches pump intake screen causing it to suck air.

Since roughly 23% of all wells drilled in New Mexico being dry holes, there is a need to perform a pump test on completed wells to verify the aquifer will produce enough water to meet the resource need. The pump test also needs to be reasonably short in duration.

The standard method of performing a pump test consists of installing a pump into the casing after development is completed and installing a monitoring well close by that would allow measurement of the drawdown curve close to the well. The pump test would begin and continue for 36 hours to 10 days maintaining a constant rate of discharge and frequently measuring the changing drawdown in the pumping and observation wells. After the pump test is completed, the

pump is stopped and the recharge is measured in both wells until the original water table depth is reestablished. The data is then evaluated and aquifer characteristics are determined.

The spreadsheet requires a computer with at least a 486/33 or better (586 is better); Windows XP or better, Excel version 7.0 or better. NRCS workstations meet these requirements.

Step by Step Procedure. As soon the well is complete and developed, a test pump is installed to verify the aquifer yield. The spreadsheet assists in verification of the aquifer suitability in meeting the resource need and allows for proper pump design and placement.

The initial pumping rate should begin at the calculated resource need. During the pump test if the drawdown level is not steady and is increasing, the pump rate needs to be reduced until the drawdown level (depth) remains constant. Once the drawdown remains constant, the test continues for one hour. This duration establishes if the aquifer can supply the resource need or not. The recorded pump rate and drawdown depth are input into the spreadsheet along with the casing size and pre-test static water depth.

All measurement depths input into the spreadsheet are measured from the top of casing at the surface down to the water table. The initial depth to water will always be smallest number prior to the pump test. The next depth will be the depth to water from the surface down to the steady state water level, which is the depth to the bottom of the cone of depression (pumping depth) at the end of the one hour pump test. The largest depth is from the surface down to the bottom of the well pump screen.

Following is a step by step process showing how to use the spreadsheet. You must be present at the well site during the pump test with the spreadsheet on a laptop computer.

Step 1 – The driller/contractor must understand that the well is not complete until it has been pumped to determine its capacity and drawdown and does not yield undesirable sediment when pumped at the desired capacity. The driller/contractor should perform the pump test before leaving the job.

Step 2 – After the driller/contractor is finished drilling and developing the well, he must install the pump to be used for the pump test, have a flow meter, and a valve to control the discharge during the pump test.

Step 3 – Obtain from the driller/contractor the depth down to the intake screen of the pump (#1), the diameter of the well casing in inches (#2), and the pre-pumping water depth before the pump test begins (#3).

Step 4 – Input the above three variables into the spreadsheet and include the pump test pumping rate (#4). At the beginning of the pump test, this should be the calculated resource need.

Step 5 – Start the pump test, adjusting the pumping flow rate, usually with a valve located on the outflow pipe at the surface. The driller/contractor should install a flow meter on the output pipe to verify discharge and insure that the flow rate is constant.

Step 6 – Measure the water depth in the well as it drops and levels off to a static equilibrium level and record this depth (#5). If this pumping depth (depth to water surface during pumping) reaches the intake screen of the pump, then reduce discharge until an equilibrium water level is above the intake screen with a reasonable buffering distance (about 5 feet above the pump's intake screen.

Step 7 – Input the equilibrium depth into the spreadsheet (as the "Input 1 hour Pumptest constant depth" in feet).

Step 8 – The spreadsheet results calculate the time to empty the casing plus add the minimum pump test duration in hours.

Step 9 – Continue the test for the recommended minimum pump test time measuring the water surface depth and discharge on regular intervals. A constant depth and the constant pump rate for 60 minutes confirms that equilibrium has been reached.

Step 10 – Once completed, discontinue the test, remove the driller/contractor's test pump, complete the design of the permanent pump, and install the proper pump for the correct pumping depth and rate for the aquifer.

Step 11 – Save the spreadsheet, print the results and include in the producers file and submit the pump test results to the State office.

In the spreadsheet, the formula in cell G17 solves for Qt. This value Qt corresponds to maximum pumping rate just before the well pumps all of the available water down to the top of the well screen. Recommended pumping range of the well pump should be between 75-90 percent of the maximum capacity. Cells G15 and G16 calculate the recommended pumping rate range for the well.

At the beginning of the pump test, the pump must empty the casing storage volume completely and allow for the aquifer to recharge the well. This will actually test the aquifer and obtain the correct information to properly design the pump for this specific well. Cell G18 calculates the time it takes to empty the casing storage volume based on the total drawdown in feet of water in the casing being pumped at the given constant pumping test rate. Cell G19 calculates in hours the total minimum pump time to empty the casing storage and complete the one hour pump test. This time assumes a constant rate until the drawdown maintains a constant level.

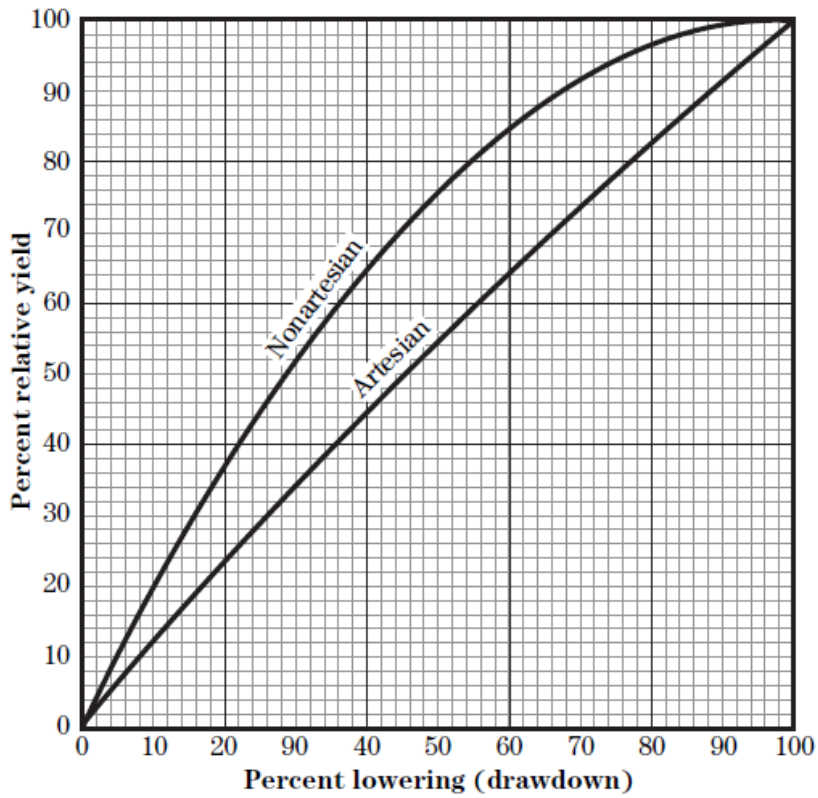
The calculated drawdown and capacity in percent is calculated based on the actual pump rate. The recommended pumping rate ranges between 75% and 90% and is calculated by the spreadsheet. The estimated maximum pumping rate is calculated for the well and the estimated time to pump out the casing storage is calculated. Adding 60 minutes to the time to empty the casing storage determines the minimum pump test time in hours, which is required for the pump test.

Development of Confined/Unconfined Aquifer Short Duration Pump Test. A simpler method of determining the aquifer's ability to provide enough water was developed utilizing the following simplifying assumptions: Wells are drilled in ideal conditions, with a homogenous aquifer matrix, with isotropic properties and fully penetrating wells. A relative relationship between drawdown and yield was developed for both artesian and non-artesian wells and the graph depicting the relationships is in Part 210-650.1203(g) (page 12-37 of Chapter 12 in the Engineering Field Manual of the National Engineering Handbook). Figure 12-29 has been extracted from that reference and is shown on the next page.

It is the intent of this analysis to place the well completed in a confined or unconfined aquifer along one of the appropriate curves by locating two points along the curve. The end points of the curves can be determined which will define the maximum pump rate for our well and establish the capacity of the aquifer to meet the resource need.

A well usually produces about 75% of its capacity when the drawdown is at half the water depth and about 90% when the drawdown is at two thirds the water depth. For most economical pumping, the pump should be designed to operate between these two extremes, since increasing the pumping rate to the maximum causes every gallon that is pumped to be lifted the total depth from the surface to the drawdown level.

Figure 12–29 Relationship between drawdown and yield



Confined Aquifer Spreadsheet Development. The curve in Figure 12-29 representing artesian wells will be used for confined aquifers. A best fit curve was generated for the artesian curve using Excel. Figure 1 displays that curve.

Fitting pump test results to the above ideal curve allows a relationship between drawdown and flow rate to be calculated. This simplified method is intended to estimate the pumped well behavior based on a short pump test. The length of the pump test is only long enough to maintain a constant flow rate, (usually at the actual resource need flow rate) with zero change in the actual drawdown for one hour time.

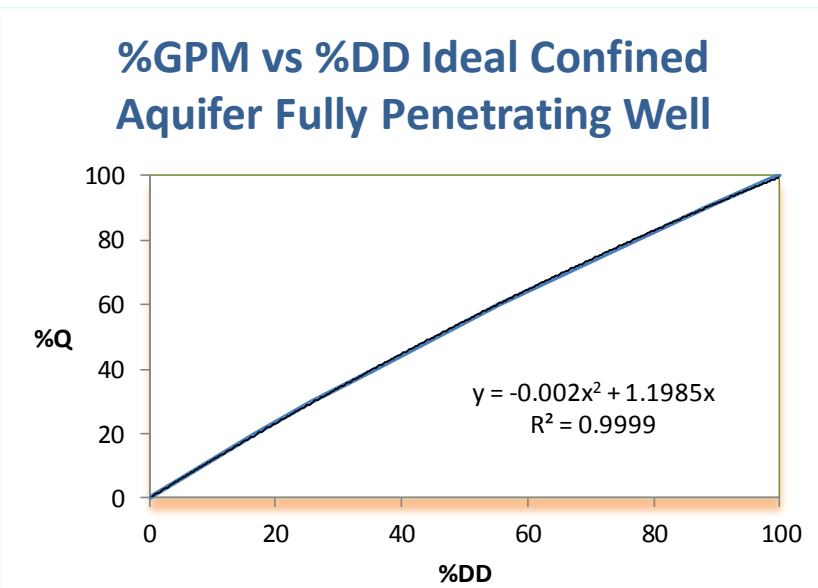


Figure 1

The following quadratic curve is the best fit curve of Figure 1 for artesian (confined) aquifers. Since $R^2 = 0.9999$, the equation is essentially a perfect fit for the curve or data.

$$y = -0.002x^2 + 1.1985x$$

Where y = percent of total flow(% gpm) or

y = (actual flow rate/maximum flow rate) x 100 or

$y = (\frac{Q}{Qt})100$

and x = percent of total drawdown (% dd) or

x = (actual drawdown during pump test/total available drawdown) x 100 or

$x = (\frac{dd}{ddt})100$

Substituting variables for % gpm and % dd in the equation:

$$\left\{\left(\frac{Q}{QT}\right) * 100\right\} = -0.002 * \left\{\left(\frac{dd}{ddt}\right) * 100\right\}^2 + 1.1985\left\{\left(\frac{Q}{QT}\right) * 100\right\}$$

The known values are:

Pumping rate (Q) in our pump test;

Drawdown in the well at that pumping rate (dd); and

Total available drawdown down to the intake screen of the pump (ddt).

The only unknown variable in the equation is the maximum pumping rate (Qt), hence rearranging the equation and solving for Qt:

$$Qt = \frac{100Q}{-.002\left[\frac{dd*100}{ddt}\right]^2 + 1.1985\left[\frac{dd*100}{ddt}\right]}$$

Solving for Qt establishes our location on the curve and the endpoints of the curve thereby allowing our ability to calculate our well capacity and design a proper pump for installation.

Unconfined Aquifer Spreadsheet Development. The Non-artesian aquifer curve in Figure 12-29 represents unconfined aquifers. A best fit curve was generated for this curve using Excel. Figure 2 displays the results.

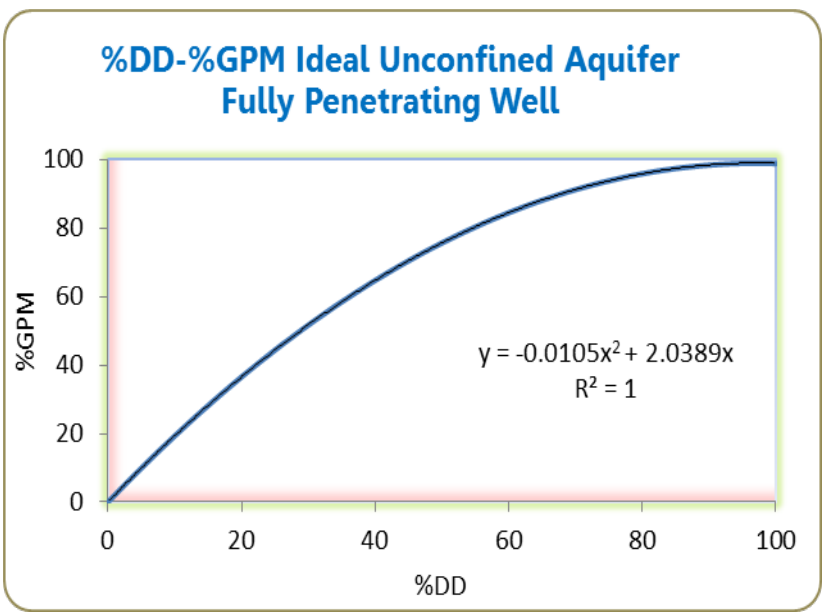


Figure 2

Fitting pump test results to this ideal curve allows a relationship between drawdown and flow rate to be calculated just like the confined aquifer derivation above but with different formula. The unconfined aquifer pump test is also intended to estimate the pumped well behavior based on the same short aquifer pump test. The length of the pump test is only long enough to maintain a constant flow rate, (usually at the pumping rate defined by the resource need) with zero change in the depth of drawdown for one hour.

The following quadratic curve is the best fit curve of Figure 2 for non-artesian (unconfined) aquifers. Since $R^2=1$, the equation is a perfect fit for the data.

$$y = -0.0105x^2 + 2.0389x$$

Where y = percent of total flow(% gpm) or

y = (actual flow rate/maximum flow rate)x100 or

y = $(\frac{Q}{Qt})100$

and x = percent of total drawdown (% dd) or

x = (actual drawdown during pump test/total available drawdown) x 100 or

x = $(\frac{dd}{ddt})100$

Substitute in variables for % gpm and % dd in the equation:

$$\left\{\left(\frac{Q}{QT}\right) * 100\right\} = -0.0105 * \left\{\left(\frac{dd}{ddt}\right) * 100\right\}^2 + 2.0389\left\{\left(\frac{Q}{QT}\right) * 100\right\}$$

The known values are

Pumping rate (Q) in our pump test;

Drawdown in the well at that pumping rate (dd); and

Total available drawdown down to the intake screen of the pump (ddt).

The only unknown variable in the equation is the maximum pumping rate (Qt), hence rearranging the equation and solving for Qt:

$$Qt = \frac{100Q}{-.0105\left[\frac{dd*100}{ddt}\right]^2 + 2.0389\left[\frac{dd*100}{ddt}\right]}$$

Solving for Qt establishes our location on the curve and the endpoints of the curve thereby allowing our ability to calculate our well capacity and design a proper pump for installation.

This analysis and short duration pump test procedure was developed by Chuck Braden, PE, Environmental Engineer, NRCS, Albuquerque, NM